(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
22 December 2005 (22.12.2005)

PCT

(10) International Publication Number
WO 2005/120727 A1

(51) International Patent Classification[7]: B06B 1/00, B05D 1/26, B05C 11/00, G06F 7/00

(21) International Application Number: PCT/US2003/031949

(22) International Filing Date: 8 October 2003 (08.10.2003)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/421,214 25 October 2002 (25.10.2002) US

(63) Related by continuation (CON) or continuation-in-part (CIP) to earlier applications:
US 10/115/536 (CIP)
Filed on 3 April 2002 (03.04.2002)
US 60/421,214 (CIP)
Filed on 25 October 2002 (25.10.2002)

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(81) Designated States (*national*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG,

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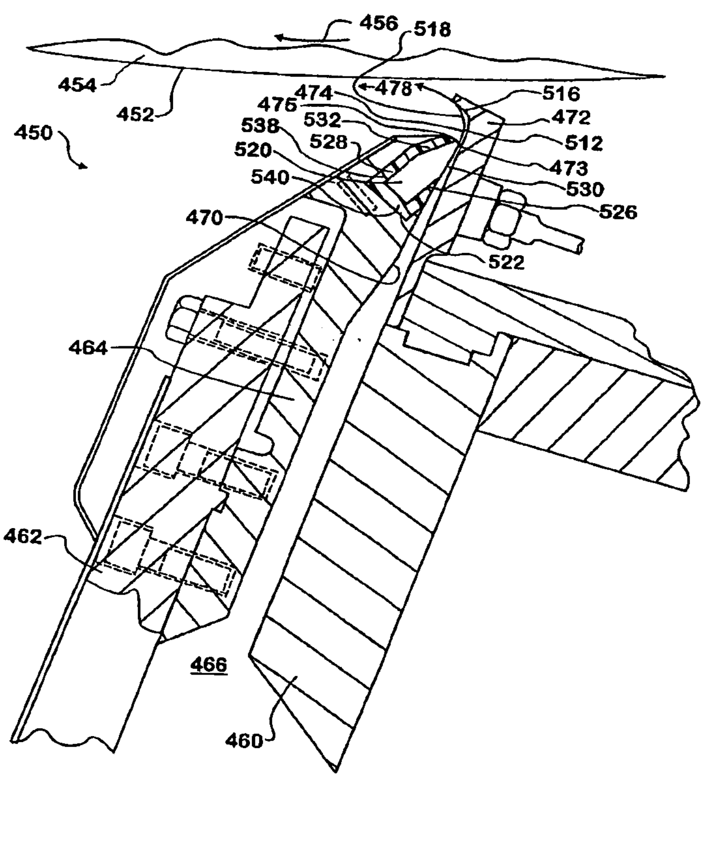
(54) Title: COATER WITH SONIC OSCILLATOR METHOD AND APPARATUS



(57) Abstract: A coater for (450) a moving paper web (452), preferably of the jet type, is disclosed and provided with a sonic oscillator (520) forming a portion of the discharge orifice or exit tip (475), which is preferably adjacent the discharge of the coater (450) and which is opposite the side of the discharge likely to be applied the moving web (452). The sonic oscillator (520) keeps the orifice or tip (475) clean while minimizing any effect of the oscillator (520) on the coating actually applied to the web (452). The invention covers both a method and apparatus. A method, apparatus, system, and computer program product for clearing flow disruptions in the coating applicator and a web inspection system are also disclosed. The latter is downstream of the applicator (450) to detect coating defects and communicate a cross-machine location of the defect to activate vibrations at that location to clear the flow disruption.

WO 2005/120727 A1

Rec'd PCT/PTO 20 APR 2005
PCT/US2003/031949
10/532161

COATER WITH SONIC OSCILLATOR METHOD AND APPARATUS

This PCT application is a continuation-in-part of U.S. Patent application Serial No. 10/115,536, filed April 3, 2002, entitled "Method and Apparatus for Reducing Fluid Flow Disruptions, Rajendra Deshpande, inventor, and U.S. provisional application Serial No. 60/421,214, filed October 25, 2002, entitled "Coater with Sonic Oscillator Method and Apparatus", Wayne A. Damrau and Michael Piontek, inventors. This invention relates to a method and apparatus for a paper coater, and more particularly for a method and apparatus for keeping an application nozzle, orifice, slot, or gap of the coater free of accumulations, while effecting the removal of entrained air in the applied coating. The present invention is also related to methods, apparatuses, systems, and computer program products for clearing or reducing fluid flow disruptions in the application of coatings to substrates such as paper.

Background of the Invention

It is known to use a coater to apply a coating onto a web of moving paper, either directly on a papermachine, which would include the coater or coaters on a papermaking machine, or on off machine application on a separate coater machine including the coater or coaters.

Certain types of coaters have coating apertures, gaps, or orifices through which the coating to be applied by the coater is applied to the web. It is desirable, if not essential, that the aperture or orifice be kept free of coating build up, which could cause timewise and/or spacially inconsistent coating application on the web, such as streaking or other localized discrepancies. One type of such coater is known as a jet coater such as described in U.S. Patent No. 6,319,552, which is hereby incorporated by reference. This type of coater has downstream (with respect to coating flow) one or more edges which form the orifice or aperture from which a jet of coating is forced in a stream, curtain, or jet onto the web. During operation the coating tends to coagulate and/or build up on these edges and tends to disrupt the uniform flow of coating to the web and/or results in inconsistent delivery of coating to the web. The build up could also include fiber bundles, dried coating and coating lumps. Such disruptions and inconsistencies can, if not attended to

by cleaning, cause coating skips and/or streaking and other abnormalities in the paper such as low gloss, off-color, printing defects, etc. Streaking can generally be considered the absence of coating on parts of the web. These build ups can also deny lubrication to portions of the doctor, particularly of a blade type, resulting in a portion of the blade remaining and running dry and possibly blade damage and subsequent production losses and downtime, such as due to web marks, increased clean up time, blade wear and downtime for blade changes.

Heretofore, it has been proposed to apply sonic and/or ultrasonic oscillation to the apparatus that controls the clearance of the upstream lip or surface defining this aperture, orifice or gap, this lip or surface being the one directly next to coating likely being applied to the web. Such structure and method is shown in U.S. Patent Application Serial No. 10/115,536, filed on April 3, 2002 in the name of Rajendra Deshpandi, and assigned to Stora Enso North America Corp., the assignee of the present application, which application is incorporated by reference herein.

While the invention in the above application has been found to work, it has a relatively complicated structure requiring many actuators across the web, and more importantly is situated on and oscillates or vibrates the lip that is next to the coating that likely will be applied to the paper. Any inconsistencies that the vibration or ultrasonics may cause could be directly on the very coating that is likely being applied to the paper. The actuators themselves are actually some distance away from the lip and cause the lip to vibrate. For example, if these actuators were 8 inches apart, a web 20 feet wide would use 30 such actuators.

It is also known to use a sonic rod, in, for example, a separate wash tank to clean parts, such as for example, the grooved doctor rods of a paper coater. Such type cleaning systems have been offered by Voith Sulzer Paper Technologies, Inc., under the name Roll Flex Rod Cleaning Device. It should be understood that such use is not on the actual coater itself, but is an auxiliary piece of equipment, a cleaning tank, for cleaning disassembled coater parts, i.e., the doctor rod.

Coating a web of paper is generally effected by the application of a liquid coating material onto a moving web. The coating material may be comprised of a solid constituent suspended in a liquid carrier. The quality of the coating applied onto the paper

web depends upon a number of factors, an important one of which being how the material is applied. The application of the coating material should preferably result in a coating that is smooth, continuous and uniform across the web.

Fountain coating of paper is a coating process in which the liquid coating material is jetted in a free-standing curtain of coating liquid directly onto the moving web with a fountain applicator. The fountain applicator comprises an elongate nozzle that includes a metering aperture, orifice or slot for communicating the coating fluid onto the web. The nozzle extends in a cross-machine direction coextensive with the paper web moving adjacent to it and supported by a backing roll. A downstream doctor blade meters and smoothes the coating. The amount of coating applied to the web may be controlled by controlling the size of the metering orifice or slot and pressure of the coating fluid. Desirably, a substantially uniform coating layer is applied across the width of the web. Fountain coating applicators are generally known in the art, with examples disclosed in U.S. Patent Nos. 5,436,030 to Damrau and commonly owned by the assignee of the present application, which is hereby incorporated by reference.

Despite many years of practice, unresolved problems remain associated with paper coating. For example, impurities such as fiber bundles, dried coating, coating clumps, foreign matter, and the like, occasionally clog the nozzle metering orifice or slot and disrupt coating flow. Coating defects in the form of streaks or other inconsistencies can result. Paper production with streaks or other defects, cannot be sold. Further, if a clog is not removed quickly, the coater blade may not receive adequate lubrication and become damaged. Blade replacement requires costly machine downtime, with resultant production losses.

Summary of the Invention

In the apparatus and method of the present invention oscillation is provided on and at the very edge of the downstream lip of the coater, on the coating that is away from the coating that is likely to be applied to the web, that is next to the coating jetted from the coater but that is the least likely to be applied to the web. In more particular the one embodiment of the invention a Sonotrode bar or rod is located at the downstream side (with respect to web travel) of the nozzle of a jet type coating applicator. This type vibrator will also be referred to as a sonic rod. Thus, it is believed that any adverse effect

on the coating actually being applied to the web is minimized. Unlike prior art devices, this sonic rod or bar is placed and forms the downstream (with respect to web travel) side and edge or exit tip of the nozzle, aperture, orifice or gap. The structure of the present invention is very much simpler as only one or two sonic rods may be used. Unlike the prior art, the sonic rod, preferably, forms one part of the very end of the exit tip of the gap. This rod or bar will generate a sonic or an ultrasonic frequency or vibration which will cause this tip and the lip it forms and adjacent jetted coating and any accumulation to vibrate with amplitude. This action clears and/or prevents any accumulation or build up in the adjacent area without adverse effect on the coating. The amplitude is chosen so that the portion of nozzle aperture, orifice or gap being oscillated will accommodate a motion of about 10 microns.

While it is envisioned that placement of the sonic rod to form the tip will be most beneficial, of course the sonic rod could be located elsewhere, and will still retain some advantages of the present invention. For example, the sonic rod could be placed somewhat upstream with respect to coater flow (i.e., not exactly at the tip) or on the upstream (with respect to web travel) edge of the nozzle. In the latter alternative, the advantage of oscillating the coating away from that likely being applied to the web may not be obtained. The foregoing upstream and downstream references with respect to web travel are with respect to a Voith Jet Flow F or other type applicator. This type of applicator may utilize a curved lip or surface to turn the coating before jetting it onto the web. Of course, the curved surface could be open as with a curved sheet, or enclosed as with an elongated slot such as shown in Figures 4 and 7 of the 6,319,552 patent or in a Valmet type jet coater.

If the present invention is utilized with a type jet applicator not having a curved surface, then the rod would preferably be located on or at the lip adjacent to the coating most likely to be bladed off and not adjacent to the coating most likely to be applied to the web. It is believed that the present invention due to its simplicity, results in a cost effective installation over the use of many prior art separate actuators to cause sonic oscillation. While an actuator type prior art installation may cost $400,000 (U.S.) for a coater, the present invention could be done for an estimated savings of between $350,000 and $300,000 (U.S.). Further, there is an additional advantage as it is believed that the

sonic oscillator at the tip of the nozzle or orifice will cause air bubbles to collapse and result in a more air free coating being delivered to the web or sheet. It is believed that the present invention enjoys all the advantages of the inventions set forth in above-mentioned 10/115,536 and 60/421,214 applications which are herein, as noted above, incorporated by reference. In addition, the present invention is believed to enjoy operating advantage over present coaters without oscillation in the form of less downtime for clean up and doctor blade changes due to irregular blade wear.

The present invention is also directed to apparatus, method, system, and computer program product embodiments for reducing and clearing clogs and other flow disruptions in coating applicators. A method embodiment of the invention generally comprises the steps of vibrating at least a portion of the nozzle at an oscillation or frequency. The vibrations have a frequency more or less than about 20 kHz, an intensity that may be at least about 3G, and a magnitude of less than about 10% of the minimum gap width of the nozzle metering slot. An apparatus embodiment of the invention comprises a fountain coater having a vibrator attached thereto for vibrating at least a portion of the fountain coater at a frequency of more or less than about 20 kHz if desired at an intensity of at least about 3G, and at a magnitude of less than about 10% of the minimum gap width of the metering slot. A system embodiment of the invention comprises combining an apparatus embodiment with a downstream inspection means for detecting coating defects and communicating a signal to the vibrator after detecting the defect. Preferably ultrasonic, sonic, or if desired magnetorestrictive or other type vibrators may be used to produce the desired movement, frequency or vibrations.

Embodiments of the present invention solve otherwise unresolved problems in the art. It has been discovered that vibrations of relatively high frequency sonic or ultrasonic high intensity, and low magnitude are particularly effective to clear clogs and other fluid flow disruptions. Taking advantage of the frequency nozzle application and/or use of the preferred vibrators results in favorably high energy vibrations with relatively low energy input.

The above brief description sets forth broadly some of the features and advantages of the present disclosure so that the detailed description that follows may be better understood, and so that the present contributions to the art may be better appreciated.

Before explaining example embodiments of the disclosure in detail, it is to be understood that the disclosure is not limited in its application to the details of the specific embodiments set forth in the following description or illustrated in the drawings. The invention may take the form of modified and further embodiments, as will become apparent from this disclosure. Also, it is to be understood that the terminology employed herein is for description and not limitation.

Brief Description of the Drawing

Figure 1 is a schematic elevational view of a coater station illustrating an embodiment of the invention.

Figure 2 is a schematic perspective view of a coater system embodiment of the invention.

Figure 3 is a cross sectional view illustrating the method and apparatus of the present invention embodied on a jet coater of the type made by Voith Sulzer GmbH.

Figure 4 is a flow chart illustrating a computer program embodiment of the invention.

Figure 5 is a view similar to Figure 3, but showing the coater exit lips adjacent one another and shows the sonic rod enclosed in a removable, replaceable easily serviced portion of the coater.

Figure 6 is a view similar to Figure 5, but shows the sonic rod in a jet coater made by Valmet.

Figure 7A is a first view taken on the lines 7-7 of Figure 5, showing a coater with two sonic rods having overlapping inner ends.

Figure 7B is a second view similar to Figure 7A also taken on the lines 7-7 of Figure 5, but showing two sonic rods having abutting inner ends.

Description of the Preferred Embodiment

Before discussing several embodiments of the invention in detail, it will be appreciated that the discussion herein and the drawings may be useful in describing any of method, apparatus, system, and/or computer program products embodiments of the invention. Accordingly, it will be understood that discussion herein related to any of the embodiments of the invention may relate to other embodiments. By way of example, it will be appreciated that a computer program product embodiment may comprise computer

readable instructions stored in a computer readable medium that when executed by a computer cause the computer to carry out the steps of a method embodiment. Similarly, it will be appreciated that a method embodiment of the invention may comprise performing steps using a system or an apparatus or station, indicating generally at 2 comprising a backing roll 6 for supporting a moving paper web 8, an applicator 4, and a doctor 9. Those knowledgeable in the art will understand that the coater station 2 may be a component of a papermachine (i.e., an on-machine coater) or may be a component of an off-machine coater. The coater station 2 extends in a cross-machine directly substantially coextensive with the width of the web 8.

The applicator 4 comprises a nozzle 18 having a front wall 10 and back wall 12. The walls define a metering space 14 therebetween. The space 14 has at its exit a minimum gap width 16 that is the closest separation of the front and back walls 14 and 16. A chamber 17 communicates with the space 14. In operation a coating composition is delivered under pressure from the chamber 17 through the nozzle 18, and applied onto moving paper web 8. The nozzle 18 functions to meter the flow of coating material and impinge a uniform ribbon or sheet of coating onto the web, forming an excess coating layer 20 on the moving web. The coating layer is doctored to a desired coat weight by doctor 9.

Those skilled in the art will understand that the illustration of Fig. 1 is a general schematic only that is not drawn to scale, and that a coating station and an applicator in practice may comprise additional components. By way of example, the nozzle 18 may further comprise a curved lip, as is explained in U.S. Patent No. 5,436,030 to Damrau ("the Damrau '030 patent"), herein incorporated by reference. Additional information regarding the construction and operation of coating stations and applicators appears in the said Damrau '030 patent.

In operation, coating composition flow disruptions in one or more portions of the applicator 4 may occur. For example, particulate material may occasionally become lodged in the nozzle 18, causing disruptions in the flow of coating composition. Lodged particulate material may comprise fiber bundles, clumps of dried coating composition, foreign materials, and the like. Disruptions in the flow and application of coating material onto the web 8 cause streaks and other defects in the coating layer.

It has been discovered that coating flow disruptions in the applicator nozzle 18 are substantially avoided or cleared by vibrating at least a portion and preferably the exit tip of the nozzle 18 with vibrations of a frequency, intensity, and magnitude sufficient to free the lodged matter from the nozzle 18. It will be appreciated that as used herein, the term "intensity" when used in relation to a vibration is intended to broadly refer to energy associated with a vibration, which is proportional to the acceleration of a part or plate. Intensity may thus be measured in terms of acceleration of a vibrating part or member, with a useful unit of measurement being the gravitational pull on earth ("G") of $9.8 m/s^2$ The term "magnitude" as used herein in reference to vibration is intended to broadly refer to a measure of distance a vibrating member travels during vibration, with units of measure of length useful for reference.

One type of vibrator may be made of a magnetorestrictive material. Generally, magnetorestricive materials are characterized in that a strain may be caused in them through application of a magnetic field. This characterization may be manipulated to cause vibrations of a desired frequency through cyclical application of a magnetic current. Additional details regarding technology and operation of magnetorestrictive devices are available in the literature, for example, "Magnetorestrictive Materials and Ultrasonics," by T. Toby Hansen, Chemtech, American Chemical Society (August 1996).

Preferably, the vibrator 24 is part of the nozzle 18 of the applicator where clogging is likely to occur preferably at tip or exit. The vibrator 24 may be attached to an internal portion of the applicator 4.

As illustrated for example in the perspective view of Figure 2, in the preferred apparatus embodiment of the invention, one, or more, vibrators and its driver 24 are connected to the applicator nozzle. It should be understood that one or two vibrators and their drivers could be used, one at each side of the web, or just a single vibrator extending across the web, with one driver at one of the ends of the web. The spacing of the vibrators, in order to achieve satisfactory vibration, has been discovered to depend on the geometry of the applicator and nozzle, including the location of supports or anchor points along the applicator. In the preferred embodiments of the invention the one or more vibrators generate vibrations at a desired frequency.

It will be appreciated that the present invention is not limited to one vibration

frequency. Indeed, one may generate vibrations at virtually any frequency found to be practical for a particular application. Preferably, however, vibration frequency will be sonic or ultrasonic. Frequencies greater than 20 kHz are generally referred to as ultrasonic.

It is desirable that the vibrations of the present invention generate relatively high intensity. Preferably, vibration intensity may be at least about 3 G. It has been found that this level of intensity may be successful in removing clogs and other nozzle flow disruptions. Somewhat lower intensity levels (e.g., 1-2 G) are also at least partly successful. Intensity levels greater than 4 G are most preferred as these have been found to have a very high success rate.

In addition to frequency and intensity, it has been discovered that the magnitude of the vibrations should be minimized, but adequate to do the job. In addition, high vibration may tend to "pinch" the applicator slot closed which could cause flow disruptions, and undesirable coating layer thickness variations. It is believed that a magnitude of vibration that is less than about 10% of the minimum gap width will avoid these undesirable results. More preferably, the vibration magnitude should be kept below about 5% of the minimum gap width. It is also believed that magnitudes below about 3% of the minimum gap width will be useful. It is also desirable that some minimum magnitude is achieved, with a useful lower bound believed to be about or less than 1% of the minimum gap width. By way of particular example, the minimum gap width of the metering slot for many paper coaters will be on the order of about 0.8 - 1 mm. it has been discovered in embodiments of the present invention, that good results were achieved with a vibration magnitude of about 24 micron for a minimum nozzle slot of 0.8 - 1.0 mm (i.e., a ration of about 3% to about 5%). Even low magnitude will work, depending on the nature on the vibrator.

When considering vibration frequency, intensity, and magnitude in combination, embodiments of the invention are believed to offer advantageous results when frequency is about 20 kHz, more or less, intensity is at least about 3 G, and magnitude is maintained at a ratio of less than about 10% of the minimum nozzle slot gap width. Vibrations having these qualities are useful for clearing particulate or other matter that may otherwise attach to the surface of the nozzle. The vibrations are believed to separate the clog from the

nozzle wall, which is thereby freed and drawn away by the flow of coating fluid through the nozzle. It is also believed that the vibration frequency, intensity, and magnitude ranges of invention embodiments do not undesirably effect the coating composition. While the above-discussed limits on frequency, intensity, and magnitude are believed to be useful for practice of the preferred embodiments of the invention, it will be understood that practice of the present invention is not necessarily limited to these parameters. That is, other embodiments may be useful using vibrations with one or more of intensity, frequency, and/or magnitude values that fall outside of these limits.

Embodiments of the present invention may comprise continuous operation of the one or more vibrators 24. However, the present sonic rod disclosed herein may not be capable of continuous operation, but a specially developed sonic rod might. This continuous operation may be advantageous for preventing coating defects from occurring. However, continuous operation may also entail, however, relatively high-energy costs and unnecessary fatigue on the coater equipment. As an alternative to continuous operation, then, the present invention further contemplates additional control schemes for selective or otherwise non-continuous vibrator operation. These invention embodiments may be desired, for instance, to achieve energy, equipment wear, and other savings.

Additional vibrator control schemes for practice with embodiments of the invention comprise manual operation whereby the vibrators are manually turned on and off to resolve disruptions, and intermittent operation whereby the vibrators are cyclically timed or turned on for first period of time and of for a second period of time. When a plurality of vibrators are present and attached along the cross-machine dimension of an applicator, additional control schemes may comprise sequential operation of the vibrators in a reoccurring pattern. By way of example, a controller such as a wave generator may be used to generate a recurring sin wave or a square wave pattern along the cross-machine width of the applicator by sequentially operating the vibrators.

For example, if two sonic rod vibrators are used they may be operated independently or sequentially.

Still other control schemes for operation of the vibrators comprise a feedback type of control, such as that shown in Figure 2. For simplicity, the components that are similar to those described in Figure 1 are given a reference numeral 200 numbers higher, i.e.,

blade 9 of Figure 1 is blade 209 of Figure 2. A system embodiment of the invention 200 may further comprise an electronic web inspection system 230 downstream of the coater station 202. Preferably, the inspection system 230 is placed downstream of the doctor 209. The inspection system 230 may comprise a plurality of individual sensors mounted, for instance, above the moving web on a support bar or the like. The sensors may comprise any suitable means for inspecting the web, with examples including but not limited to, visual inspection means such as electric eyes, infrared detection devices, or other forms of radiation.

An example of commercially available web inspection systems believed to be useful for practice of an invention embodiment comprises the ULMA Nti Web Inspection System available from ABB Instruments, Ltd., St. Neots, Cambs, England. Inspection means such as the ULMA System utilize optical sensors like charged coupled device ("CCD") cameras to detect and identify defects in the paper web such as holes and coating streaks. A light source illuminates the web and the CCD cameras detect variation in intensity. Image processing computers then analyze the variations. The system is capable of providing information regarding the exact type and location of the defect.

The inspection system 230 inspects the web downstream of the coater station 204 to detect coating defects or other irregularities. By way of example, the inspection system 230 may be used to detect streaking, surface irregularities, or other indications that the flow of coating fluid through the applicator 204 is being clogged or otherwise disrupted. The inspection system may comprise a single, reciprocating sensor. Alternatively the inspection system may comprise a plurality of sensors spaced along the width of the web 208 such that a given sensor corresponds to a particular vibrator or vibrators. Each of the sensors may then be used to monitor a particular portion of the web along its cross-machine width. Each of the particular portions of the web corresponds to one or more of the vibrators. When a defect is detected in a particular cross-machine location of the web, the electronic inspection means 230 may communicate a signal instructing that one or more of the sonic rods and driver 224 remove the defect. As shown in Figure 2, a system embodiment of the invention may further comprise a controller 236 and communications lines 234, 235 for communicating with and controlling the web inspection system 230 and/or the one or more vibrators 224.

In a feedback based control scheme, an example of which is disclosed in Figure 2, operation of the one or more vibrators 224 may continue for a pre-determined amount of time. For example, time periods of about 5 seconds have been found to be useful. Further, it is believed that of time periods of no more than 20 or 30 seconds should be sufficient for achieving good results with practice of the invention. Other control schemes modifications may be used, for example, a feedback control scheme could include programming the web inspect system to communicate a second signal for terminating vibration upon concluding that a coating defect has been cleared or otherwise resolved.

The controller 236 may comprise any of a number of processor-based tools for control and communication with the web inspection system 230 and the one or more vibrators 224. Examples include, but are not limited to, computers such as a personal computer, a laptop, handheld computer, a PLC (programmable logic controller), or a mainframe or server computer communicating with over a network, as well as dedicated processor based devices, program instructions running on a computer device, circuitry such as a printed circuit card or chipset, and the like. Further, it will be appreciated that the controller 236 is not limited to being a "stand alone" device as illustrated, but may for instance be contained, physically or functionally, within one or more of the web inspection systems 230, coater controller (not illustrated), or the like. Additionally, a single controller 236 may be used to control the one or more vibrators and web inspection systems on a two or more coater stations. The controller preferably communicates with the inspection system 230 and the one or more vibrators 224 via the communications lines 234, 235 or which may comprise a wireless connection such as an RF connection or the like, a LAN connection such as an ethernet, a WAN connection, a POTS connection, or any other suitable communication line.

It will be appreciated that variations are possible within the scope of the invention using a web inspection system as illustrated by Figure 2. For example, a single electric eye may be used that has a field of vision traversency or spanning the entire width of the web and that could provide a reference for width location of coating defects. Alternatively, a single sensor could be used that was operated to relatively quickly scan the width of the web through movement across the web on a track, through pivotal rotation, or the like. The controller could be used to control and monitor this movement

so that when a defect was discovered a corresponding vibrator could be activated.

As an additional example, a control logic embodiment of the invention may comprise activating more than a single vibrator in response to detection of a defect. For example two vibrators could be activated corresponding to a particular web region of interest as well as the neighboring zones. Or, if the defect was detected near one edge of a zone, one or two vibrators could be turned on corresponding to the web region of interest and the region nearest the edge where the defect is located. Further, it should be understood that the inspection regions and the vibrator regions need not correspond on a 1:1 basis. For example, one vibrator region may cover many inspection regions. Accordingly, as used herein the term "corresponding" when used in reference to relations between the web inspection and vibrators will be broadly interpreted to include any relationship whereby detection of a defect at a particular location on the web may "correspond" to a vibrator location.

Other control scheme embodiments may be provided to conserve energy and costs. For example, an additional variation on continuous operation of the vibrators may be timed operation wherein only one of the two vibrators are operating at a given time. By way of example, the vibrators may be turned on sequentially along the cross-machine width of the applicator 204, with one to two of the vibrators activated at any given time. Timed, sequential operations schemes may be used to generate square waves or sin, or other form, waves in exit lip of the applicator nozzle.

It will also be appreciated that the invention is not limited to practice with a single vibration frequency, intensity, and magnitude values. For example, vibrations could be initiated as desired at a relatively low magnitude, frequency, and intensity and then gradually increased until a defect is resolved.

It will be appreciated that the present invention may be useful in the form of a computer program product. Accordingly, it will be understood that the present invention may take the form of a computer program product for controlling a nozzle vibration system, the program product comprising computer readable instructions stored in a computer readable medium that when executed cause the computer to carry out steps of a method embodiment of the invention. It will be appreciated that the computer readable medium for storing the instructions may comprise any of a number of suitable mediums,

with examples including, but not limited to, optical, magnetic, circuitry, micro-circuitry, and the like. Further, the term "computer" as used herein is intended to be broadly interpreted to describe any processor-based apparatus capable of executing program instructions. It will additionally be appreciated that computer program product embodiments of the invention will be useful for causing a computer to carry out method steps as have been discussed herein and for controlling systems as have been discussed herein.

Figure 4 is a flowchart illustrating the logic of an example computer program product embodiment 200 or 300 of the invention. The program product embodiment 200 or 300 causes a computer to inspect a web for coating defects using a web inspection system (block 302). If a defect is detected (block 304), the computer causes a signal to be communicated that indicates at least the cross-machine location of the coating defect (block 306).

After communication of this signal, the computer actuates at least one vibrator to vibrate a portion of the applicator nozzle that corresponds to the cross-machine location of the defect (block 308). The vibrator preferably generates vibrations at a desired frequency and a desired magnitude less than about 10% of the nozzle minimum width. In this program product embodiment 300, a feedback control scheme is used to terminate vibrations. That is, the computer causes the web inspection system to determine whether the coating defect has been resolved (block 310). If not, vibrations are continued (block 308). If the defect has been resolved, vibrations are terminated (block 312). Other control schemes for controlling vibrator operation could of course be practiced with other computer program product embodiments of the invention. For example, upon detection of a defect, the program product may cause the vibrator to operate for a pre-determined amount of time, with an example period comprising about 5 seconds or less, say 2 seconds.

Referring to Figure 3, a jet type coater or applicator similar to that known as a Jet Flow F manufactured by Voith Sulzer GmbH is generally shown at 450. This coater has been modified to illustrate the incorporation use of the sonic rod type vibrator and may be used with the systems 200 shown in Figure 2 and/or 300 shown in Figure 3 of the present invention.

The applicator, itself, (without the present invention) is also similar to that described in Figure 2 of the U.S. Patent 6,319,552.

More particularly, the fountain applicator of Figure 3 is indicated generally at 450 and applies onto a surface of a moving paper web 452, which is carried past the applicator on a backing roll 454 that rotates in a direction as shown by an arrow 456, an excess layer of coating liquid that is doctored to a desired coat weight by downstream doctor means such as a blade (not shown in the present application but shown in Figure 1 hereof and U.S. Patent 6,319,552). The fountain applicator is part of a papermachine having on line coating capability or a separate coating machine, and extends in the cross-machine direction, parallel to the backing roll 454 and transversely of, across and spaced from the backing roll supported web. The applicator has front and rear walls 460 and 462, and attached to the upper end of the rear wall is a plate 464. The front and rear walls and the plate form a coating distribution chamber 466 therewithin, into which liquid coating material is delivered under pressure via a coating liquid distribution pipe that extends longitudinally through the chamber and has a plurality of coating outlet openings spaced longitudinally therealong. The front and rear walls may be hinged at their lower ends for movement apart to provide access to the chamber 466 for cleaning.

A metering slot 470 is defined between the front wall 460 and the plate 464. The metering slot extends upwardly from the chamber 466 and transversely of and across the backing roll supported web 452, and from bottom to top is inclined toward the front of the applicator to enhance a migration of air entrained in the coating liquid upwardly toward the side of the metering slot defined by the plate. A replaceable elongate deflector tip 472 is at the upper end of the front wall and an elongate outlet aperture, orifice, gap or nozzle 474 from the metering slot is at the top of the plate 464 between the plate and the deflector tip. On its side toward the outlet nozzle, the deflector tip has an elongate concave curved surface 478 that is positioned proximate to, transversely of and spaced from the web. Coating liquid exiting the elongate outlet nozzle flows in a sheet along and then off of the curved surface in a free standing sheet or jet curtain of coating liquid that is directed against and across the web surface at an appropriate included acute angle. If desired, the downstream end of the coating liquid flow surface of the deflector tip could terminate in an elongate flat surface (not shown) of relatively limited length beyond the curved surface

478, along which the coating liquid sheet would flow after leaving the curved surface and before being projected toward the web in a free standing sheet or jet curtain of coating liquid. Adjustable deckle devices (not shown) may be at opposite ends of the elongate outlet nozzle to control its transverse extent and, therefore, the transverse extent of the sheet of coating liquid, thereby to control the width of the coating layer applied onto the web.

In operation of the fountain applicator 450 and with reference to Figure 3, coating liquid delivered to the applicator by the coating supply system is introduced into the distribution pipe and flows through the pipe openings into the chamber 466.

More specifically, coating liquid delivered into the chamber 466 flows upwardly through the metering slot 470 and exists the elongate outlet nozzle 474 in an elongate sheet of coating liquid that extends transversely of the paper web 452. The sheet of coating liquid flows along the deflector tip to the concave curved surface 478, where the sheet is forcefully flowed against the curved surface as its direction of flow changes to conform to the curved surface. As set forth in the 6,319,552 patent, causing the coating liquid 512 sheet to follow the curved surface subjects it to a centrifugal force that causes the dense coating liquid to move toward one side 516 of the sheet that is toward the curved surface and the much less dense air entrained in the coating liquid to move away from the one side and toward an opposite side 518 of the sheet that is away from the curved surface, so that the one side of the coating liquid sheet is relatively free of entrained air. After flowing along the curved surface, the sheet of coating liquid flows off of the deflector tip in a free standing elongate sheet or jet curtain of coating liquid directed toward, transversely across and against the paper web surface. In consequence, the web surface is contacted primarily with the one side 516 of the coating liquid sheet that is relatively free of entrained air, while the opposite side 518 of the sheet of coating liquid, toward which the entrained air has moved, is out of substantial contact with the web, so that there is a decrease in the occurrence of skip coating with the web surface. The layer of coating liquid applied onto the web by the applicator is in excess and is doctored to a desired final coat weight by the downstream doctor means. It is one purpose of the present invention to minimize any disturbance of this air bubblefree coating that is being applied to the web, while eliminating blockage or clotting of the delivery gap or orifice.

By way of example, if the outlet aperture, orifice, gap or nozzle 474 has a width of 0.048" and a length of 17", and if 5,000 cps viscosity coating liquid at 20 rpm Brookfield is flowed through the nozzle at a rate of 25 gallons per minute, then the cross-sectional area A of the nozzle is 0.816 square inch, the volume flow rate Q of coating through the nozzle is 5.775 cubic inches per minute and the average velocity V of coating liquid through the nozzle is Q/A, i.e., 590 feet per minute. If it is assumed that there is a 35% reduction in effective nozzle gap due to the coating having zero velocity at the nozzle walls, then the fastest average velocity of coating liquid through the nozzle is 590/(1.00-.35) i.e., 908 feet per minute.

With an outlet nozzle width of 0.043 inch, coating liquid flow rates from the nozzle can range from about 1.25 gallons per inch nozzle length in the direction transverse of the web to about 3.10 gallons per inch length, so for a nozzle having a length of 122", total flow rates of coating liquid through the outlet nozzle would be on the order of 170-380 gallons per minute. At such flow rates, the velocity of coating liquid flowing out of the nozzle would be in the range of about 560-1,375 feet per minute. Coating liquid is therefore emitted from the outlet nozzle and impinged against the web surface at relatively high velocities.

While in the fountain applicator 450 shown in Figure 3, the coating liquid curved flow surfaces 478 of the deflector tip 472 are exposed to the outside of the applicator and located downstream (with respect to coating flow) from the metering slot 470 and the elongate outlet nozzle 474, the liquid flow curved surfaces could be part of and located within the fluid flow path defined by the metering slot 470 and/or within the coater structure itself, like that shown in Figure 4 and 7 of the said U.S. Patent No. 6,319,552.

The aperture, orifice gap or nozzle outlet of the jet coater 450 as noted forms an upstream (with respect to web travel) wall 472 having an upstream surface 473 and a downstream (with respect to web travel) wall 464 having a downstream tip 475. As noted in the apparatus and method in this embodiment of the present invention, one side (downstream with respect to web travel) of the very exit tip is formed by the vibrator or sonic rod 520. As is shown the sonic rod has been machined or otherwise formed to have a lower flat wall 522, an upstream wall 526, a downstream wall 528, an upstream tapered or inclined wall 530, a downstream taper or inclined wall 532, with the tip 575 being

formed by the upstream and downstream taper or inclined walls 530 and 532. Of course the sonic rod could be machined into some other suitable shape forming at least one side of the exit tip.

To accommodate movement of the tip with a minimum or no disturbance of the remainder of the coater, the sonic rod 520 and its tip 475 are encapsulated or mounted elastically 538 to the coater in a larger but complimentary shaped cavity 540 in the wall 464. For example, the tip is encapsulated in an elastomeric rubber or plastic which would permit the amplitude or movement of around ten microns, but yet be compatible with coating and its constituents. For example, material such as silicone rubber, polyurethane, or the like, might be used.

Preferably the tip and its encapsulation are readily removable and replaceable in the coater, should the sonic rod malfunction or the tip or elastomeric elastic wear.

It is believed the operation of the present invention is apparent from the foregoing drawing and accompanying disclosure. Briefly when desired, or even continuously, the sonic rod is actuated and vibrated or oscillated, and this oscillation causes the tip 475 to oscillate. The oscillation of the tip 475 prevents and/or breaks up any accumulation of coagulated coating or other materials on the tip. It is believed that while only the upstream lip 475 is oscillated, this oscillation will keep both the upstream lip and opposite downstream surface 473 and the entire aperture, orifice or nozzle gap of the coater clear. It is also believed that this vibration or oscillation will help free up small air bubbles in the coating and/or collapse the same to deliver a more air free coating to the web.

The sonic rod could be of the type made by Martin Walter company of Europe and would comprise an ultrasonic driver or generator with automatic frequency control and amplitude adjustment. PZT High Output Converters are used in cooperation with the sonic rod to provide ultrasonic energy to the nozzle tip or surface 75. These drivers or generators can be mounted outside the machine and/or web, as shown in Figure 1 (24), Figure 2 (324) and Figure 7A or 7B (723A, B, C or D). Other forms of sonic or ultrasonic generators, such magnetorestrictive devices, could be used and are within the scope of invention and the claims.

It is thought that frequencies in the range of 20,000 Hz would be suitable with amplitude in the range of 10 microns. Nodes located where there is no amplitude at a

specific frequency is of concern as the web in a cross-machine direction could be up to 30 or more feet. In such situations, the frequency of the sonic or ultrasonic rod or vibrator might be varied to move the nodes or spacing therebetween along the axis of the sonic rod and across the width of the web to fully cover the entire web width. Such node movement may make them less noticeable by spreading or compressing the space between the nodes. Alternatively more than one sonic rod could be placed in the encapsulation and operated at different frequencies to have the two vibrators at each location and overlap and the amplitude or one rod mask the nodes of the other rod.

The invention is believed, can be installed economically, and particularly at much lower cost than a multiple actuator system. Further as noted above, the invention will deliver a more air free coating jet, or curtain to the paper web, due to the oscillations collapsing air bubbles at the nozzle tip. Yet further, it is believed the invention will result in greater production due to less downtime due to less need for clean up and less blade wear and blade changes. Additionally, it is believed the present invention could be retrofitted into already existing coaters as well as being built into new coaters.

The present invention could also be adapted to the type coater shown in Figures 4 and 7 of U.S. Patent No. 65,319,552.

Referring to Figure 5, another embodiment of applicator 600 is partially shown. This application like that shown in Figure 3, could be incorporated into the systems shown and discussed with respect to Figures 2 and 4. This coater has similar parts numbered similar to those shown in Figure 3, except they are in 200 numbers higher, i.e., sonic rod 520 of Figure 3 is 720 in Figure 4. The principal changes in Figure 5 is that the two lips 672 are closely adjacent each other. The fountain applicator of Figure 5 is indicated generally at 650 and applies onto a surface of a moving paper web 652, which is carried past the applicator on a backing roll 654 that rotates in a direction shown by an arrow 656. An excess layer of coating liquid is applied and is doctored to a desired coat weigh by downstream doctor means such as a blade (not shown). The applicator has front and rear walls 660 and 662, and attached to the upper end of the rear wall is a sonic rod carrying replaceable member 665. The front and rear walls and the member form a coating distribution chamber 666 therewithin, into which liquid coating material is delivered under pressure via a coating liquid.

A metering slot 670 is defined between the front wall 660 and the tip 775. A replaceable elongate deflector tip 772 is at the upper end of the front wall 660 and an elongate outlet aperture, orifice, gap or nozzle 674 forming the metering slot is at the tip of the member 665. On its side toward the outlet nozzle, the deflector tip has an elongate concave curved surface 678 that is positioned proximate to, transversely of, and spaced from the web. Coating liquid exiting the elongate outlet nozzle flows in a sheet along and then off of the curved surface in a free standing sheet or jet curtain of coating liquid that is directed against and across the web surface at an appropriate included acute angle.

In operation of the fountain coater 650 and with reference to Figure 5, coating liquid delivered to the applicator by the coating supply system is introduced into the distribution pipe and flows through pipe openings into the chamber 666. The flow in coater 650 is generally similar to that of coater 450, except at the tips 675. It is believed that the construction of coater 650 insures that all the coating is likely to be applied to the web, with little or no backflow, particularly at slower speeds such as at start up to running speed, say from slow speeds to 1000 plus feet per minute, resulting in less paper production losses. Like coater 450, coater 650 causes the coating liquid sheet to be forcefully flowed against the curved surface as its direction of flow changes to conform to the curved surface. As set forth in the 6,319,552 patent, causing the coating liquid sheet to follow the curved surface subjects it to a centrifugal force that causes the dense coating liquid to move toward one side 516 of the sheet that is toward the curved surface and the much less dense air entrained in the coating liquid to move away from the one side and toward an opposite side 518 of the sheet that is away from the curved surface, so that the one side of the coating liquid sheet is relatively free of entrained air. After flowing along the curved surface, the sheet of coating liquid flows off in a free standing elongate sheet or jet curtain of coating liquid directed toward, transversely across and against the paper web surface. In consequence, the web surface is contacted primarily with the one side of the coating liquid sheet that is relatively free of entrained air, while the opposite side of the sheet of coating liquid, toward which the entrained air has moved, is out of substantial contact with the web, so that there is a decrease in the occurrence of skip coating with the web surface. The layer of coating liquid applied onto the web by the applicator is in excess and is doctored to a desired final coat weight by the downstream doctor means.

Also, the present invention minimizes any disturbance of this air bubble free coating that is being applied to the web, while eliminating blockage or clotting of the delivery gap or orifice and minimizing entrained air. The dimensions and flow rates for coating 650 are similar to those mentioned above for coater 450.

The aperture, orifice gap or nozzle outlet of the jet coater 650 as noted forms an upstream (with respect to web travel) wall 672 having an upstream surface 673 and a downstream (with respect to web travel) wall 664 having a downstream tip 675. As noted in the apparatus and method in this embodiment of the present invention, one side (downstream with respect to web travel) of the very exit tip is formed by the vibrator or sonic rod 720. As is shown, the sonic rod has been machined or otherwise formed to have a lower flat wall 722, an upstream wall 726, a downstream wall 728, an upstream tapered or inclined wall 730, a downstream taper or inclined wall 732, with the tip 775 being formed by the upstream and downstream taper or inclined walls 730 and 732. Of course, the sonic rod could be machined into some other suitable shape forming at least one side of the exit tip.

To accommodate movement of the tip with a minimum or no disturbance of the remainder of the coater, the sonic rod 720 and its tip 775 are encapsulated or mounted elastically 738 to the coater in a larger but complimentary shaped cavity 740 in the wall 764. For example, the tip is encapsulated in an elastomeric rubber or plastic which would permit the amplitude or movement of around ten microns, but yet be compatible with the coatings and used their constituents. For example, material such as silicone rubber, polyurethane, or the like, might be used for the encapsulating.

Preferably the tip and its encapsulation and the complimentary surrounding supporting member 665 are readily removable and replaceable in the coater as a unit, should the sonic rod malfunction or the tip or elastomeric elastic wear. The member 665 provides additional structural support against bending for the sonic rod. The member 665 has a tee shaped element at its bottom which can receive mounting holts or other fastening means 667 to hold the member 665 in place on the member 662-662'. Such support provided by member 665 may be needed on very wide webs and coaters, say over 20 feet to up to and beyond 30 feet, which would use long sonic rods of 10 or 15 feet or 20 or 30 feet in length.

Referring to Figure 6, another embodiment of the invention is shown, this time on a coater like that made by Valmet. Again, the numerals to the extent they describe similar parts are the same as on Figure 3 but 400 numbers higher, i.e., Figure 3 front wall 460, becomes front wall 860 in Figure 4.

The operation, sizing, coating flow, advantages, clearing of obstructions and reduction of air bubbles and entrained air is similar for that for coater 450 of Figure 4 and coater 650 of Figure 6, and need not be further described in detail to a person skilled in the art for such will become apparent form the foregoing.

Like coaters of Figures 3 and 4, that of Figure 6 can also be used with the computer or detection systems of Figures 2 and 4.

While a single vibrator or sonic rod can be used such as shown in Figure 1, with the rod extending across the entire machine width with its driver at one of the sides, more than one can alternatively be used as previously mentioned. Referring to Figures 7A and 7B, instead of having a single vibrator or sonic rod, one or more (a plurality) of sonic rods or vibrators could be used. The reference numerals used in Figures 7A and 7B are the same as those for Figure 5. For example, two sonic rods (720A and B or 720C or D) could be used, one extending inward from each of the two sides of the machine (664, 665). The drivers (723A, 723B, 723C, 723D) for each rod could be located at the two sides of the web and machine. Preferably, the rods 720A and 720B or 720C and 720D would be equal length so as to be interchangeable with its corresponding rod 720B and 720A or 720D and 720C, and in such case would meet at or near the center line of the machine. Of course, unequal length rods could be used and then the two would meet their inner ends off center. To prevent marking, when two rods are used, the joint or juncture of the two rods should be "fine" and close. If need be, this joint could be potted and machined and/or polished so as to be seamless and leave no mark on the web or its coating.

Additionally to assure removal of any defect near the joint or juncture of the two rods, they could be tapered and/or overlap (see 725A and 725B) as shown in Figure 7A or be closely machined and abutted (see 725C and 725D) as shown in Figure 7B.

It is believed that in either the overlap construction of Figure 7A or the abutting relation of 7B should permit excitation or vibration of either sonic rod and/or both sonic

rods to remove defects at the joint or centered between the rods. Another disadvantage of the split rod or double rod construction is that only the sonic rod closest to the defect on the web need be vibrated or excited, thus extending the operating life of the sonic rod and reducing replacement costs and lost time to replace a spent or nonworking rod.

It is worthy to note that at a given frequency there will be nodes spaced periodically across the coater where the sonic rod or bar will have no amplitude. The frequency then needs to be varied slightly so the nodes can be moved to provide a cleaning motion across the entire nozzle.

A web instruction system may be used to optimize the Sonotrode rods ability to keep the nozzle clean. Software can be configured to determine the cross machine location of a defect. The frequency of the Sonotrode needs to be controlled so a node is not at the location of the defect. Varying the frequency will change the location of the nodes across the length of the Sonotrode. The Sonotrode could also be controlled by a timer so that at a given interval, set by the operator, the nozzle would be cleaned. Other ways of Sonotrode operation are also possible based on the needs of the operator. It is anticipated the continuous operation of the Sonotrode will not be necessary. As noted earlier, any of the Figures 5, 6, or 7 constructions could include the systems of Figures 1 and/or 4. As used herein, paper includes light weight papers say 20 lbs. basis weight through heavy weight papers say 120 lbs. basis weight and board, such as cardboard or heavier used say for example packaging. Also the term sonic and ultrasonic are interchangeable and unless related in a claim to a specific frequency are defined to mean a useable vibration.

It will also be appreciated that although discussion and description herein has been made to a particular paper coater apparatus, method, system and computer program embodiments such discussion and description is made by way by example only. Accordingly, it will be understood that the present invention is defined by the appended claims is not limited to any of the particular embodiments described above. While embodiments of the invention have been described in detail, various modifications elements and steps and other embodiments thereof may be devised by one skilled in the art without departing from the spirit and scope of the invention, as defined in the appended claims.

What Is Claimed Is:

1. A method of applying a coating liquid onto a surface of a moving web of paper with an applicator having an elongated width outlet orifice, comprising the steps of:

flowing coating liquid, though said elongate width outlet orifice spaced from and transversely of the web;

directing the coating liquid, after it has flowed through the elongate outlet orifice, in a free standing elongate jet curtain of coating liquid toward, across and against the surface of the web;

applying a sonic oscillation adjacent to the jet curtain on the side thereof likely not to be applied to the web for keeping the orifice clean;

applying with the jet an excess layer of coating liquid onto the web surface; and

wherein the orifice of the jet may be kept clean and more streak free coated paper may be produced as the orifice is not clogged.

2. A method as in Claim 1, comprising applying a first sonic oscillation to one portion of the web and applying a second sonic oscillation to another portion of the web.

3. A method as in Claim 2, wherein said first sonic oscillation is applied to about one half the width of the web.

4. A method as in Claim 1, wherein the applying a sonic oscillation step is carried out at the outlet orifice.

5. A method as in Claim 1, wherein the applying a sonic oscillation is at about 20000 cycles per second.

6. A method as in Claim 1, wherein applying said sonic oscillation is in at least the sonic frequency range.

7. A method as in Claim 6, wherein applying said sonic oscillation is in the ultrasonic frequency range.

8. A method as defined by Claim 1, wherein the applicator has a nozzle for conveying the liquid, the nozzle having said outlet orifice with a minimum gap width, wherein the step of vibrating comprises vibrating the nozzle, the vibrations having a magnitude of less than about 10% of the minimum gap width of the outlet orifice.

9. A method as defined by Claim 1, wherein the method further comprises:

inspecting the moving paper web for coating defects caused by obstructing said outlet orifice downstream of the applicator; and

performing the step of vibrating at least a portion of the applicator in response to a defect to remove obstructing said orifice.

10. A method as defined by Claim 9, wherein the step of vibrating comprises using at least one sonic rod vibrator connected to the nozzle.

11. A method as in Claim 10, wherein the step of vibrating comprising using two sonic rods in said applicator.

12. A method as defined by Claim 11, wherein the method further comprises operating said sonic rods in a pattern along the cross-machine width of the nozzle wherein only one of said sonic rods are operating at any given time.

13. A method as defined by Claim 1, wherein the method further comprises controlling the step of vibrating according to a control scheme, said control scheme being selected from the group of control schemes consisting of substantially continuous operation, intermittent operation, timed operation, and manual operation.

14. A coater for coating a moving web of paper, comprising a body having a discharge orifice for jetting coating onto the web, said jetted coating having one side most likely not to be applied to the web and an opposite side less likely to be applied to the web, a sonic oscillator located at and forming the tip of said discharge orifice, said sonic oscillator being located adjacent said one side of said jet and away from the other side of said jet, whereby the coating that is next to the oscillator is less likely to be applied to the web but said sonic oscillator yet keeps the discharge orifice clean to permit the production of more streak free and higher quality paper.

15. A coater as in Claim 14, wherein said sonic oscillator is a sonic rod, said sonic rod extending parallel to the orifice.

16. A coater as in Claim 14, wherein said sonic rod forms part of the outlet orifice of said coater.

17. A coater as in Claim 14, wherein said sonic oscillator has a sonic driver, said sonic driver being located beyond the web.

18. A coater as in Claim 14, wherein said coater has two sonic oscillators, one for each side of the web.

19. A coater as in Claim 18, wherein said sonic oscillators are sonic rods.

20. A coater as in Claim 19, wherein said sonic oscillators have sonic drivers, said sonic drivers being located beyond the webs.

21. A coater as in Claim 14, wherein said sonic rod has one or more nodes of minimum vibrations, and means are provided from moving the nodes.

22. A coater as in Claim 21, wherein said means for moving the one or more nodes alters the frequency of the sonic oscillator.

23. A coater as in Claim 22, wherein should a defect occur at said one or more nodes, said means for moving the one or more nodes, moves the one or more nodes off of the defect.

24. A system for clearing flow disruptions from a coater for applying a coating composition to a moving paper web, the system comprising:

a paper coating applicator having a nozzle orifice with a metering slot therein, said nozzle for applying a jet of coating to the paper web to form coating on the paper web;

web inspection means downstream of said applicator for detecting a coating defect on the moving web; and

at least one sonic rod oscillator connected to said nozzle for vibrating at least a portion of said nozzle with vibrations in response to detection of the coating defect by said web inspection means.

25. A system as defined by Claim 24, wherein said web inspection means inspects a plurality of web portions in the cross-machine direction of the web, and wherein said web inspection means communicates a signal on detection of the defect, said signal comprising a cross-machine location of said defect.

26. A system as defined by Claim 26, wherein the web has a cross-machine width, and wherein:

said nozzle has a cross-machine dimension substantially across the web width;

said sonic rod oscillator extends substantially across the web width;

said web inspection means comprising a plurality of sensors spaced apart along the cross-machine width of the web, each of said sensors for detecting a defect in a portion of the web; and

said sonic rod oscillator is connected to said nozzle and spaced along the cross-

machine dimension of said nozzle, whereby one or more selected ones of said sonic rod oscillators are actuated in response to a defect detected by one of said sensors.

27. A system as in Claim 25, further comprising a controller in communication with said web inspection means for controlling said sonic rod oscillator.

28. A system as in Claim 25, wherein said web inspection means comprises at least one electric eye, and wherein said at least one vibrator comprises at least one sonic or ultrasonic rod oscillator.

29. A computer program product for controlling a coating applicator, the applicator having a nozzle with a slot formed therein, the slot having a minimum gap width, the program product comprising computer executable instructions stored on a computer readable medium that when executed by a computer cause the computer to:

use at least one sonic rod oscillator to vibrate at least a portion of the exit of the nozzle.

30. A computer program product as in Claim 29, wherein the applicator for applying coating to a moving web, and wherein the program instructions when executed further cause the computer to:

inspect the moving web for coating defects using a web inspection system located downstream of the applicator; and

perform the step of vibrating the at least a portion of the exit of the nozzle in response to detection of a defect.

31. A computer program product as defined by Claim 30, wherein the moving web has a cross-machine width and the applicator nozzle and web inspection system extend in a cross-machine direction substantially coextensive with the web, wherein the program instructions further cause the computer to locate defects in the cross-machine direction using the web inspection system, to communicate a signal comprising the location of defects, and to vibrate a portion of the exit of the nozzle at a location in the cross-machine direction that corresponds to the defects.

32. A computer program product as defined by Claim 29, wherein said at least sonic rod oscillator comprises two sonic rod oscillators connected to the nozzle, spaced along the nozzle in the cross-machine direction, and wherein the program instructions when executed cause at least one or the other of said sonic rod oscillators at a location

approximately corresponding to the cross-machine location of a defect to vibrate.

33. A method as in Claim 1, wherein said sonic oscillator may have one or more nodes, and the additional step of moving said one or more nodes so that the orifice may be kept clean.

34. A method as in Claim 33, wherein moving said one or more nodes is by changing the frequency driving said sonic oscillator.

35. A system as in Claim 25, wherein said sonic rod may have one or more nodes, and means for moving said one or more nodes.

36. A system as in Claim 35, wherein said means for moving said one or more nodes changes the frequency driving said sonic rod.

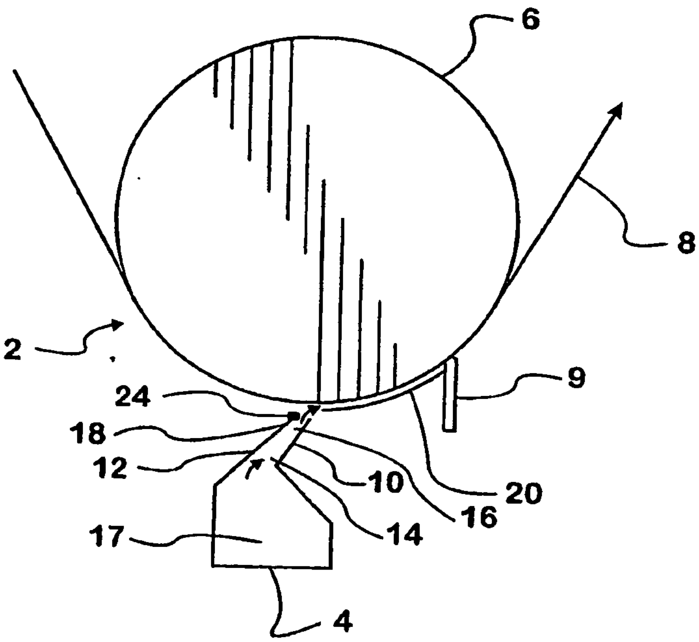


FIG. 1

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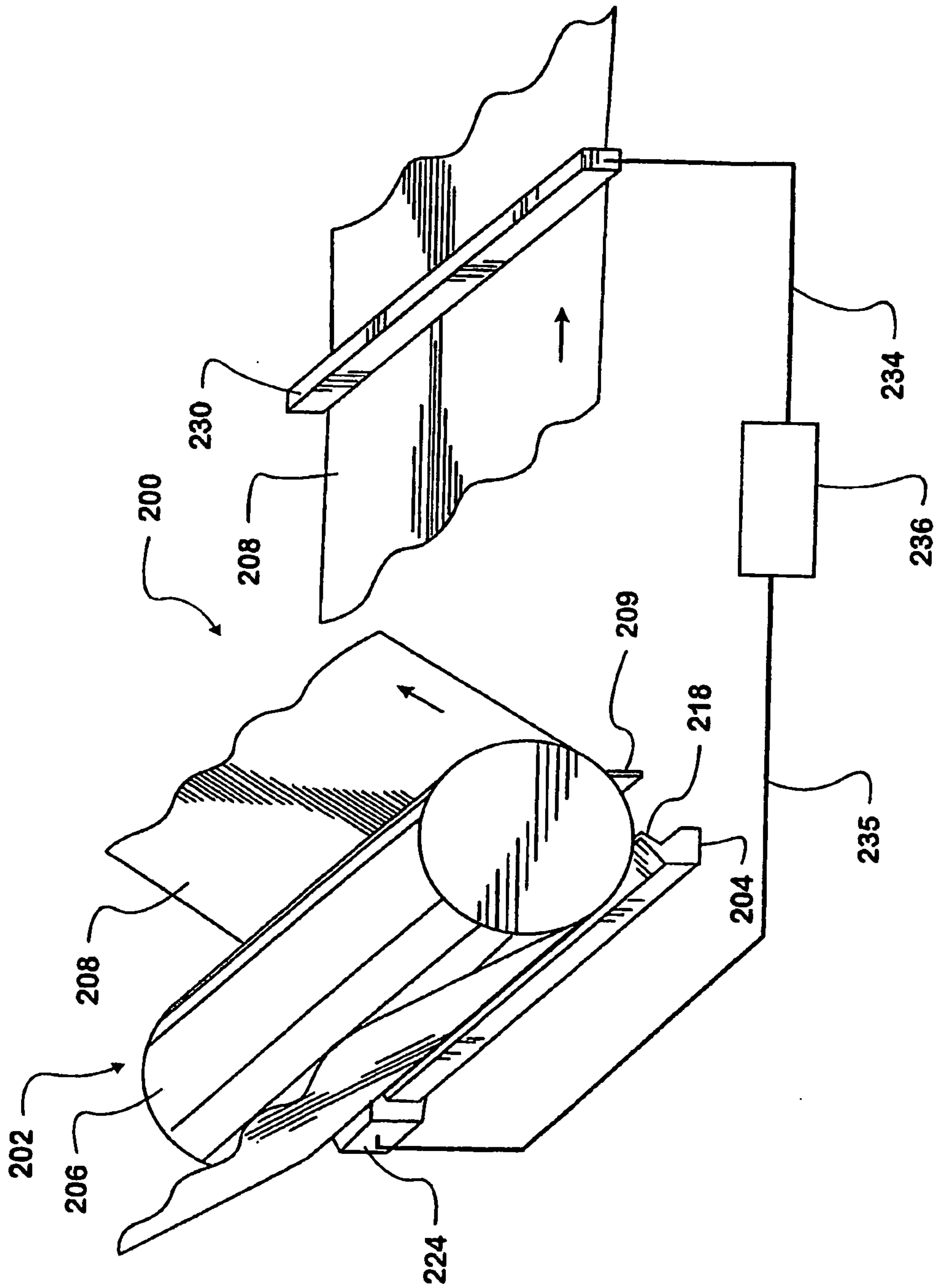
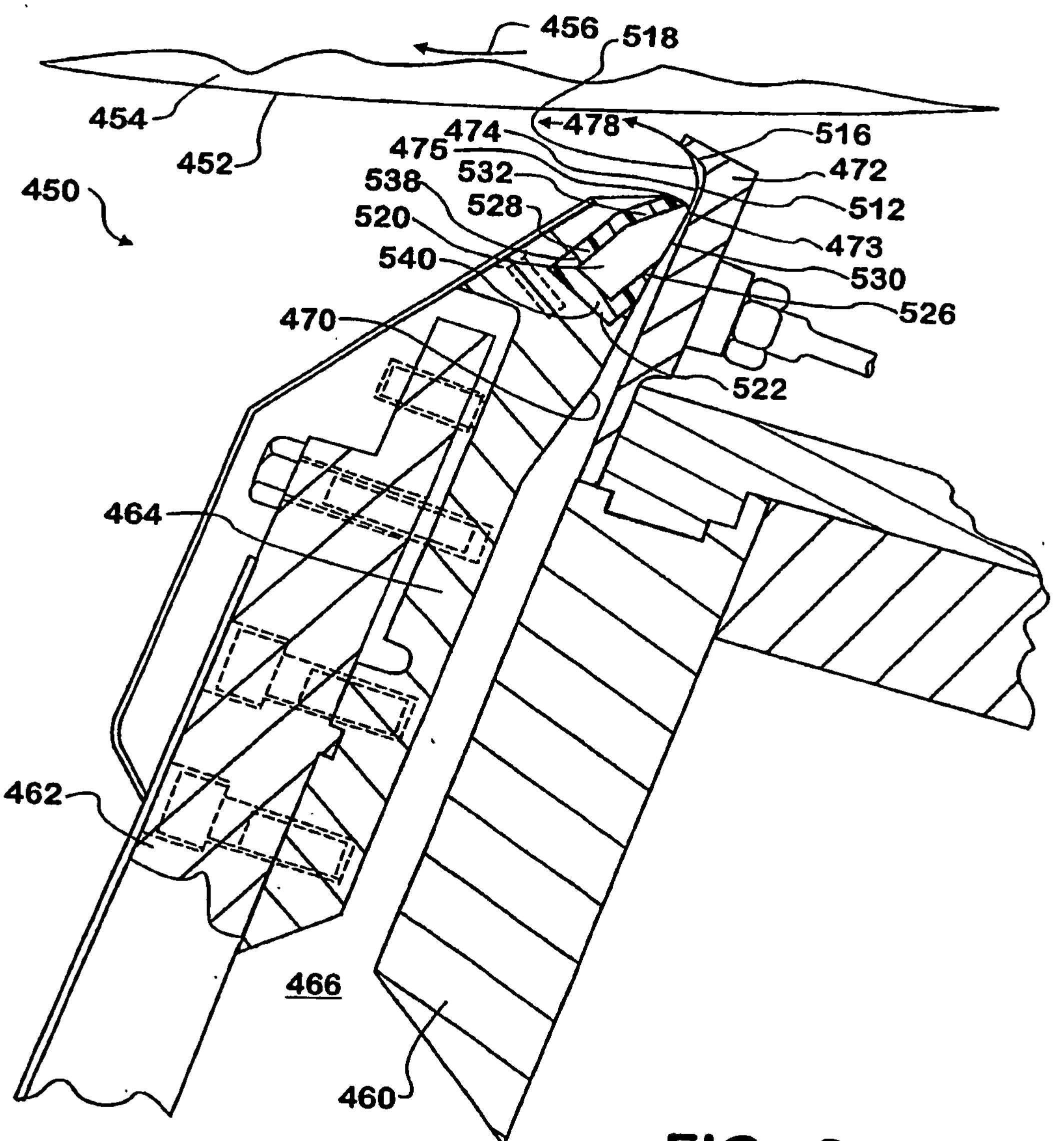


FIG. 2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464
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466
460

FIG. 3

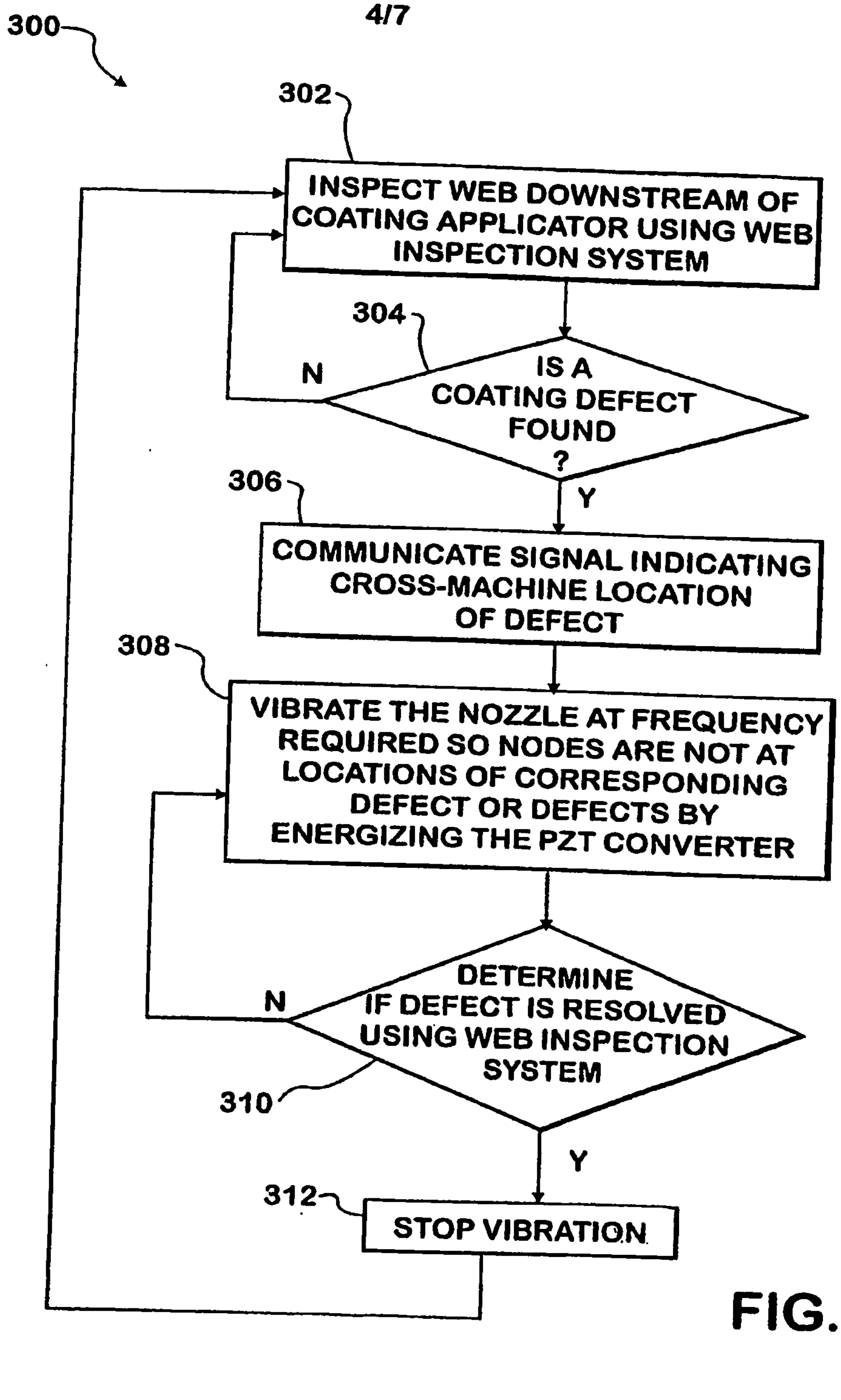
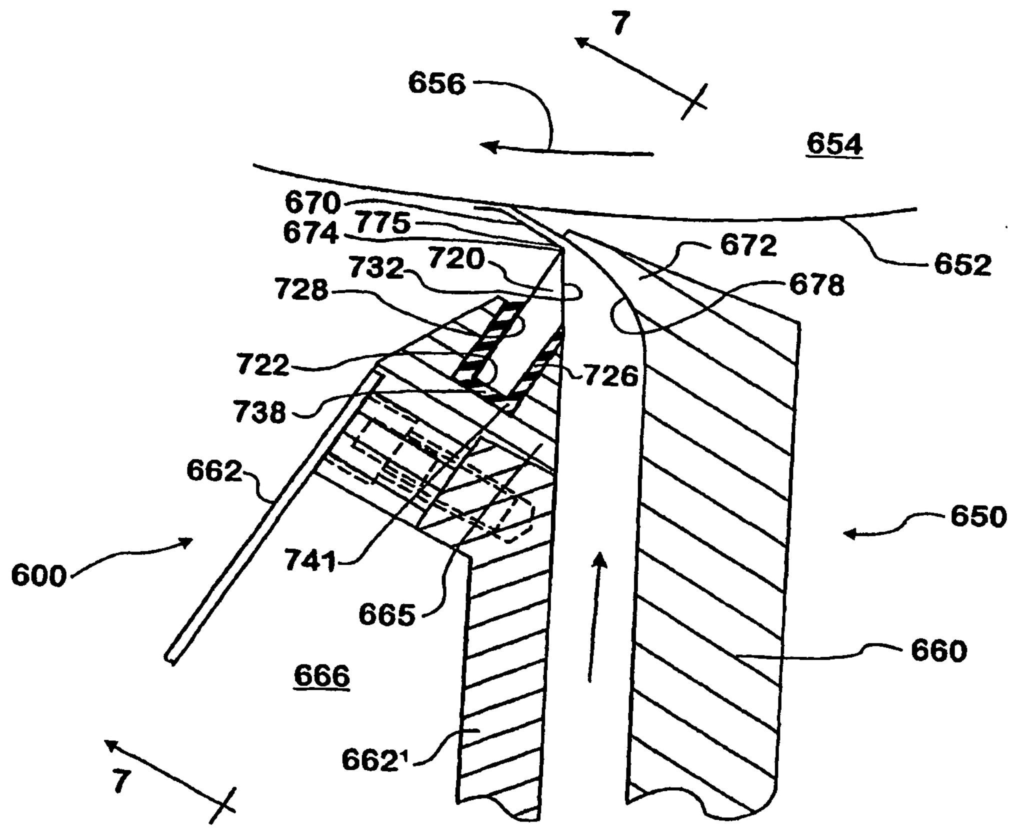

300
302
INSPECT WEB DOWNSTREAM OF COATING APPLICATOR USING WEB INSPECTION SYSTEM
304
IS A COATING DEFECT FOUND ?
N
Y
306
COMMUNICATE SIGNAL INDICATING CROSS-MACHINE LOCATION OF DEFECT
308
VIBRATE THE NOZZLE AT FREQUENCY REQUIRED SO NODES ARE NOT AT LOCATIONS OF CORRESPONDING DEFECT OR DEFECTS BY ENERGIZING THE PZT CONVERTER
DETERMINE IF DEFECT IS RESOLVED USING WEB INSPECTION SYSTEM
N
310
Y
312
STOP VIBRATION

FIG. 4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660
666
662¹
7

FIG. 5

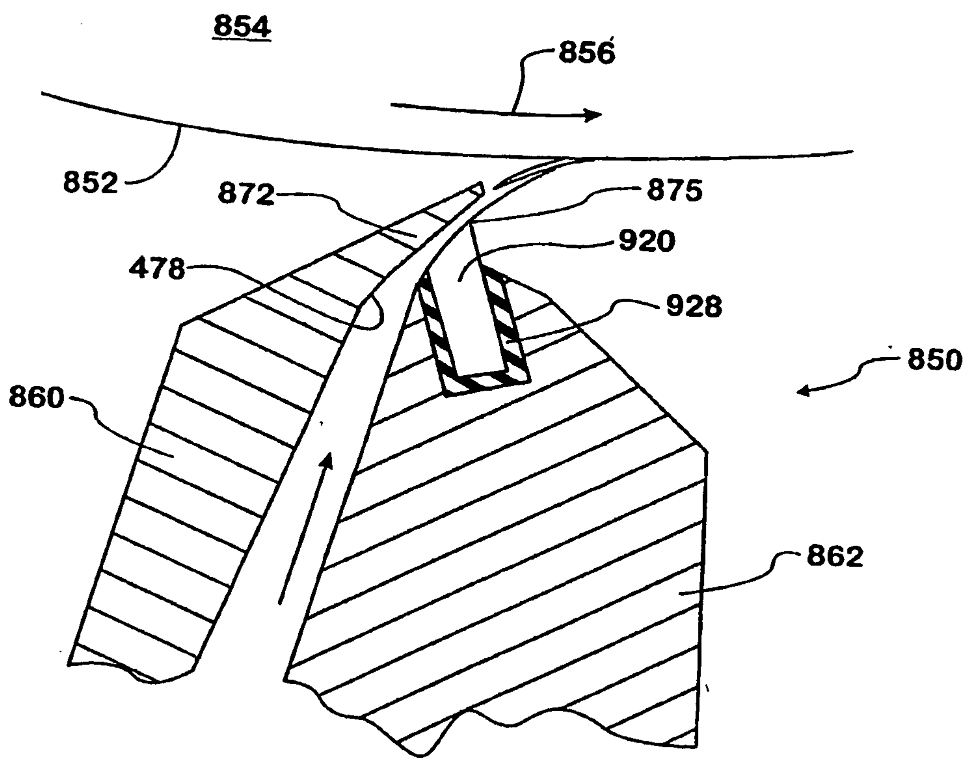

FIG. 6

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FIG. 7A

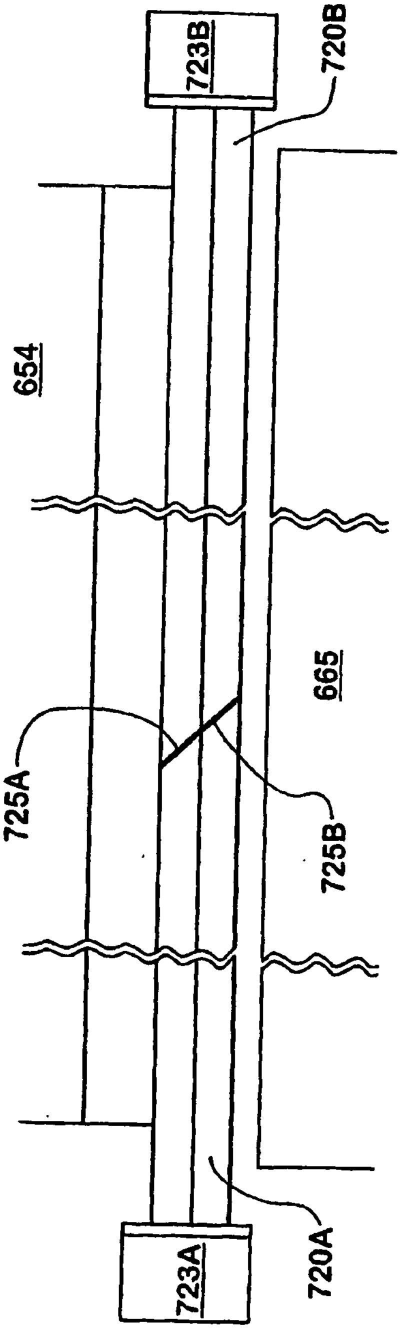

FIG. 7B